A NEUROPSYCHOLOGICAL INVESTIGATION OF CEREBRAL DOMINANCE AND DYSLEXIA

An abstract of a Dissertation by
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Numerous investigators have sought a connection between dyslexia, or difficulty in learning to read, and some identifiable abnormality of central nervous system structure or function. Building on evidence accumulated in previous studies, one experimenter, Witelson (1974, 1976, 1977), developed an explanatory theory of dyslexia based upon the concept of incomplete cerebral dominance.

Briefly, Witelson's theory hypothesizes that dyslexia occurs in those individuals whose brain functions are not sufficiently laterally specialized in the usual manner, that is, with language or verbal processing specialized in the left cerebral hemisphere, and spatial processing in the right. According to her theory, in dyslexics, spatial processing is bilateral, located in both hemispheres, which interferes with the linguistic, sequential processing in the left hemisphere.

The presence of this spatial processing activity and the lack of specialization which it implies can be experimentally measured with procedures designed to deliver sensory inputs to only one side of the brain initially. Visually, stimuli can be presented tachistoscopically to either the right or left visual hemifields, and tactually, stimuli can be presented to either the right or left hand. Since sensory inputs have been demonstrated to go directly from one hand or visual hemifield to the contralateral hemisphere, it can be determined which hemisphere is doing the processing.

Witelson employed this type of procedure with spatial stimuli to test her hypothesis that spatial processing is bilateral in dyslexics, using subjects referred from various clinics. Her results were confirmatory for tactual stimuli but were less clear for stimuli presented visually. The present study attempted to replicate Witelson's results with a school population of elementary age males and employed her tactual task, a modified visual task, and a task that was thought to be a purer measure of spatial processing. It was expected that on all three tasks non-dyslexic subjects would perform better when the stimuli were presented to the left hand or visual field, and for the dyslexic subjects the

difference between performance on right-sided and left-sided tasks would not be significant.

Thirty-five dyslexic subjects and thirty-five controls, reading at or above grade level, all aged 8-12, were selected from three area elementary schools. All subjects were administered the same three performance tasks. Task I was a visual-spatial task employing tachistoscopic presentation of data to one hemifield at a time. Task II was a tactual-spatial task employing nonsense shapes presented to both hands out of view of the subject. Task III was a tactual map-reading task requiring each subject to orient himself in space using information presented to only one hand.

For Task I, results were non-confirmatory, with both groups of subjects performing better when the left hemifield was stimulated. On Task II, both groups displayed superiority of right hand performance, again an unexpected result. Task III results were also non-confirmatory, as the trend was in the expected direction, but not statistically significant.

The generally non-confirmatory findings may be interpreted in several ways. Witelson's hypothesis of bilateral spatial processing in dyslexics may simply be in error, as some other investigators have also failed to replicate her results. Or the findings may be a function of problems in defining dyslexia, which is probably not a unitary syndrome, leading to problems in subject selection. An additional consideration is that of task validity; that is, the tasks used may need further refinement to ensure they are able to differentiate between right and left hemisphere processing.

A NEUROPSYCHOLOGICAL INVESTIGATION OF CEREBRAL DOMINANCE AND DYSLEXIA

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CHAPTER 1

INTRODUCTION

The purpose of this study is to determine the relationship between the concept of cerebral dominance or hemispheric specialization of function and the specific learning disability known as dyslexia, particularly as it relates to spatial processing. The study draws in part upon the theory and research published by Witelson (1974, 1976a, 1977). It represents a replication and extension of her work on a somewhat different population. The results of her research have supported her theory that spatial processing is a function of both cerebral hemispheres in dyslexics, whereas in non-dyslexic individuals it is primarily a function of the right hemisphere. The theory holds that this bilateral representation in dyslexics may impede linguistic, sequential processing in the left hemisphere and consequently interfere with the process of learning to read. The investigative strategy employed involves analysis of task performance scores achieved by subjects identified as normal readers as compared to those achieved by dyslexic subjects. The term "normal readers" appears throughout this paper and refers to the control subjects in the study, who were reading at or above the grade level expected for their chronological age and had never demonstrated any problems in learning to read.

The present paper will begin with a review of literature encompassing the background and definitions of the key constructs employed in this study as well as related previous research approaches. Following this review and a discussion of the rationale for the present study and hypotheses to be evaluated, this paper will specify the manner in which the above stated relationship was experimentally tested.

A total of 70 subjects was used in the study, all of whom were right-handed male students, aged 8-12, at three elementary schools in Des Moines. All subjects were free of diagnosed neurological disorder and primary emotional disturbance. Subjects were divided into two groups of 35 each, identified as either normal or dyslexic based on standardized measures of reading level. All subjects performed three different perceptual tasks designed to assess hemispheric specialization of spatial processing. It was expected that the pattern of performance on these tasks would indicate that the right hemisphere was the primary processor of spatial stimuli for the normal readers, and that neither hemisphere was dominant for the dyslexics.

The results of the study and a discussion of their research and clinical implications are presented.

CHAPTER 2

BACKGROUND

The relationship between various functions of the brain and learning disabilities has long been of concern to educators and social scientists. One area of focus in recent years has been hemispheric specialization of function, often referred to as cerebral dominance. Over a century ago, Broca inferred the localization of speech and language functions in the left side of the brain after observing aphasic deficits only in patients with left hemisphere damage. Since that time his conclusion has been validated by extensive research. Localizations of other brain functions, such as non-linquistic, spatial processing in the right hemisphere (Dimond & Beaumont, 1974; Kinsbourne & Smith, 1974), have also been established. The application of such findings to the understanding of clinical syndromes such as dyslexia, or specific reading disability, has received considerable attention in recent years.

The research study described in this paper investigates the relationship between failure to establish hemispheric dominance, a specific abnormality in the organizational development of the brain, and the clinical syndrome known as dyslexia. Before the complexities of cerebral dominance are explored, it seems desirable to devote some space to an analysis of the construct of dyslexia, as it has been the subject of considerable conceptual confusion. A brief overview is presented to acquaint the reader with some of the literature on dyslexia regarding its description and definition as well as theories of etiology.

Dyslexia: Definitions and Descriptions

The concept of "learning disability" has become significant only within the last twenty years, although educators and psychologists have been concerned with the particular problems encompassed by it. The term is employed in both a broad and a narrow, more restrictive sense. In the broad sense it covers learning failure caused by any factor or combination of factors, such as mental deficiency, sensory impairment, cultural deprivation, or emotional disturbance. In the more restrictive sense, it refers to learning failure by a child whose intelligence, sensory equipment, and cultural background appear to provide an adequate basis for learning. In this review, the more restrictive meaning will be understood unless otherwise indicated. In the opinion of many investigators the most significant type of learning disorder is that which specifically impairs acquisition of reading skills. This specific reading disability, or dyslexia, is of paramount importance because reading is so influential in determining access to other kinds of learning experiences and skills necessary for adequate functioning in our culture (Benton, 1975; Johnson, 1978; Witelson, 1977).

The multiplicity of terms used to describe reading disability has contributed to considerable confusion regarding its definition. In the literature, various researchers and clinicians have labeled this phenomenon within the framework of their own theoretical orientations. Congenital symbolamblyopia, congenital typholexia, congenital alexia, amnesia visualis verbalis, analfabeta partialis, bradylesia, strephosymbolia have all been used as terms to designate reading disabilities. More commonly used today are specific dyslexia, developmental dyslexia, congenital dyslexia, word-blindness, and congenital word-blindness (Naidoo, 1972). Such diversity of terminology and implied lack of conceptual congruence among researchers and clinicians carries over to the present day and continues to present a confusing picture to the reviewer (Benton & Pearl, 1978).

Recently efforts have been made to organize the field and produce a satisfactory definition of dyslexia, although there are several factors that tend to make the task difficult. Dyslexia is an observable phenomenon, that is, some individuals have considerable difficulty learning to read. Yet in our present state of knowledge it is unclear whether this is a unitary syndrome; in fact it seems likely that since reading is such a complex activity, there may be several kinds of "dyslexia," each with a different etiology. Research is proceeding along these lines, but there is as yet insufficient knowledge on which to base a comprehensive definition or explanation of the syndrome or syndromes. As a result, more definitional attempts have been somewhat vague. In reviewing definitions we can distinguish between the theoretical and the operational. The most often cited definition is probably that formulated at a meeting of the World Federation of Neurologists' Research Group on Dyslexia and World Illiteracy in 1968. This group defined specific development dyslexia as:

> a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and socio-cultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin (Critchley, 1970).

This definition has been criticized by several other investigators as essentially negative and raising more questions than it answers (Eisenberg, 1978; Rutter, 1978).

In writing legislation for remedial education for learning disturbances, the U.S. Congress has defined children with specific learning disabilities (most commonly dyslexia) as:

> those children who have a disorder in one or more of the basic psychological processes involved in understanding or using language, spoken or written, which disorder may manifest itself in imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations. Such disorders include such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. Such term does not include children who have learning problems which are primarily the result of visual hearing, or motor handicaps, or mental retardation, or emotional disturbance, or environmental, cultural, or economic disadvantage (U.S. Office of Education, 1976).

The distinction between specific developmental dyslexia and other forms of reading difficulty were clarified by Rabinovitch (1968), who delineated three kinds of reading disability, the first of which corresponds to specific dyslexia: (1) A primary retardation in which

> capacity to learn to read is impaired without definite brain damage suggested in the history or on neurologic examination. The defect is in the ability to deal with letters and words as symbols, with resultant diminished ability to integrate the meaningfulness of written material. The pattern appears to reflect a basic disturbed pattern of neurologic organization (Rabinovitch, 1968, p. 5).

The other two types of reading disturbance he describes are: (2) Reading retardation secondary to brain injury in which the "capacity to learn to read is impaired by frank brain damage manifested by clearcut neurologic deficits"; and (3) Reading retardation secondary to environmental factors in which "the capacity to learn to read is intact but is utilized insufficiently for the child to achieve a reading level appropriate to his mental age" (Rabinovitch, 1968, pp. 5-6). It is clear that all the above attempts at definition share a quality of vagueness and that they tend to define through exclusion rather than presenting any real explanatory mechanism.

Another way of defining specific dyslexia is operational rather than conceptual, focusing on performance characteristics observed in dyslexics. Boder (1970, 1973) classifies three types of dyslexia: (1) dysphonetic dyslexia, in which performance reflects problems in grapheme-phoneme integration and in the phonetic analysis and synthesis of words; (2) dyseidetic dyslexia, in which performance reflects deficits in the perception of symbols and words as visual configurations; and (3) mixed dyslexia, in which impaired performance is linked to both phonetic and visual disabilities.

Benton (1975) has compiled a list of eight specific errors of performance made by dyslexics, as described by various authors. They are: (1) defective visual discrimination of graphemes; (2) faulty oral reading of vowels and consonants; (3) "static" (e.g., b for d) and "kinetic" (e.g., rat for tar) reversals in reading; (4) defective word recognition in silent reading; (5) omissions and additions of words in oral sentence reading; (6) defective oral spelling; (7) excessive slowness in reading and poor retention of read material; (8) impairment in writing sponaneously or to dictation, with fair ability to copy printed or cursive material. Most dyslexics manifest some but not all of these performance deficits.

Another way of operationally classifying types of dyslexia is that of Ingram, who has divided reading errors of dyslexics into two kinds: "audiophonic" and "visuo-spatial." The former term refers to failure to realize the phonic value of letters and their combinations, while the latter term is exemplified by reversal errors and faulty visual discrimination of words that are similar in shape (Ingram et al., 1970).

The emergence of operational definitions, with their increased specificity of reference, can be seen as a necessary step in the development of dyslexia as a potential area for experimental research. Rourke (1978) suggests continuation of investigative strategies that are aimed at delineating subgroups of dyslexics. Some research has already indicated that many of the characteristics referred to above tend to occur in clusters and that it may be possible to operationally identify several subgroups within the general concept of developmental dyslexia. Mattis, French, and Rapin (1975) analyzed neuropsychological test data on 113 brain damaged and dyslexic children, and tentatively identified three syndromes: language disorder, articulation and graphomotor dyscoordination, and visuo-perceptual disorder. Doehring and Hoshko (1977) also identified "types" of retarded readers by means of the Q-technique of factor analysis. This type of research seems promising in its efforts to unravel many of the complexities involved in ariving at a meaningful understanding and definition of dyslexia.

Dyslexia: Prevalence Estimates

Prevalence estimates on reading disability range from ten to thirty percent of the total U.S. elementary school population (Benton, 1975). Such a significant spread in estimates by different investigators can probably be accounted for by the fact that any prevalence estimate is dependent on the definition used, and, as seen in the preceding section, there has been considerable disagreement over a definition of dyslexia. The higher percentage estimates often include cases which could not be strictly defined as developmental dyslexia, such as reading problems due to mental retardation, emotional or social problems, or cultural and environmental deprivation (Spreen, 1976). Benton (1975), after reviewing statements from various sources, estimates a developmental dyslexia prevalence of about 30 per 1,000 boys (3 percent) and, about 5 per 1,000 girls (0.5 percent) of elementary school age in the United States and the British Isles.

The significant difference in frequency of dyslexia between the sexes has been found over and over again and can be considered established beyond doubt. Dyslexia has also been found to have lower prevalence in Italy and Spain as compared to Northern Europe and North America (Benton, 1975). The following section reviews the historical development of dyslexia as a concept.

Dyslexia: History of the Concept

Historically, it has long been recognized that the ability to read may be impaired by brain damage manifested by obvious neurological deficits. It was noted as early as the 1860's that some patients who had sustained brain trauma lost the ability to read, often in conjunction with loss of speech. In 1877 Kussmaul, a German physician, observed that the ability to read could be lost even when sight, intellect, and speech were unaffected; he used the term word-blind. Postmortem examinations of the brains of some patients manifesting various degrees of word-blindness revealed lesions, softenings, or hemmorrhages in the occipito-parietal region of the left cerebral hemisphere. In the late 1890's cases of word-blindness where there had been no history of accident or illness began to appear in the literature, referred to as "congenital word-blindness." Several physicians attributed the condition to the mal-development of the left angular gyrus. The documentation and description of cases continued, with one researcher presenting a report of six cases affecting three generations in one family, giving rise to speculation concerning the involvement of a genetic factor. Another physician attributed the condition to cerebral damage resulting from birth injury (Gearheart, 1977). Thus, even very early on, attempts were made to link observed language difficulties with identifiable brain abnormalities. Until quite recently, however, the disparate studies of various clinicians and researchers showed little tendency to converge.

Following Cyril Burt's studies of intellectual and educational "backwardness," with their emphasis on environmental and psychogenic factors, interest in congenital dyslexia waned but was later restimulated by the work of Samuel T. Orton, a psychiatrist and neurologist, in the 1920's and 1930's. Orton worked with intelligent, apparently neurologically normal children who manifested specific reading and writing impairment and observed several characteristics to be common to many of them. These included left-handedness or mixed-handedness, frequent symbol reversals in both reading and writing (strephosymbolia), abnormal clumsiness, some difficulty in understanding spoken language, and difficulties in expressive language (Orton, 1928, 1937).

Orton was the first theorist who hypothesized that cerebral dominance was a major factor in dyslexia. He posited a direct contralateral relationship between the dominant hand and the hemisphere mediating speech and language functioning. Thus, right-handed individuals have their speech and language mediated by the left hemisphere, and this is designated the dominant hemisphere for them. Orton reasoned that the learning difficulties in oral and written language occurring in otherwise normal children might be explained by the failure of one hemisphere to assume a dominant role in directing speech and language development; this will be explored in detail in a later section. The reversal of letters and sounds could also be explained by the failure to establish cerebral dominance, and Orton reasoned that memory images are stored in both hemispheres, with the perceived orientation in the dominant, and with a reversed orientation in the non-dominant hemisphere. When one hemisphere has not attained dominance, difficulty is experienced in selecting the correct memory image or images, resulting in the reversals and transpositions he observed (Orton, 1928, 1937).

Another phase of development of the theory and treatment of dyslexia began with the initiation of limited scale remediation programs, some in private schools and university-sponsored clinics. Gillingham established a multisensory method of remediation based on Orton's theories. Another effort was that of Grace Fernald, who directed a school at the University of California at Los Angeles for dyslexic children as well as some children with other learning disabilities. Out of this program came the Fernald method, another method involving multisensory stimulation which differed from Gillingham's in vocabulary and sequence of instruction. Other widely used corrective efforts followed suit, including some using color phonics and others involving modified alphabets (Johnson, 1978).

One can discern in this brief summary of historical development the normal tendency for remedial efforts to proceed even when there is little agreement as to the causal mechanism underlying an observed syndrome.

Dyslexia: Theories of Etiology

The basic unresolved question has to do with the cause and manner of development of dyslexia. The formulations that currently merit consideration tend to overlap one another somewhat. For example, some theorists espousing a neurological basis for the syndrome attribute this to genetic factors, whereas others see the neurological deficit resulting from trauma, such as birth injury, and still others view it as due to failure to establish cerebral dominance. Similarly, some authors who adhere to what is called the maturational lag hypothesis, conceptualize a neurologically based delay in development; others, also positing a developmental lag, would attribute it to psychological or cultural factors. For the purpose of exposition, the following discussion will deal first with those theorists who emphasize the genetic factors in etiology of dyslexia, and then discuss those who try to explain a neurological mechanism underlying the syndrome.

Although a few earlier writers alluded to possible hereditary causes in the development of specific dyslexia, Thomas, a British school physician, is generally credited with the first detailed speculations concerning the operation of a genetic factor in the manifestation of the syndrome in 1905. His conclusions were based solely on observational data, as he noted many instances of more than one member of the family being affected. Thomas also observed that the preponderance of dyslexics were male (Benton, 1975).

Orton also postulated a hereditary factor in dyslexia based on his own observations, and suggested a genetic association between language deficits and left-handedness, as both were found frequently in the same families. He provided an account of nine families in which one or more language disturbance and/or left-handedness occurred in different members of the same family in three or four successive generations. In two families he reported direct inheritance of dyslexia in two generations, though he stressed that the histories were not sufficiently complete to warrant any unequivocal conclusions. Like Thomas, Orton observed that language disorders were more common among boys than girls and consequently hypothesized a sex-influenced mode of genetic transmission (Orton, 1930). Both Thomas and Orton, then, appear to have been working with a model of dyslexia as a unitary genetic trait like eye color.

Eustis (1947) reported on a family complex of 33 members, all of whom he knew personally and had studied in detail. He reported that 42 percent of the members of the family over the age of two and 48 percent over the age of six showed some combination of the following disabilities: reading disability, late development of speech, speech defects, left-handedness or ambidexterity, and unusual body clumsiness. He concluded that these specific manifestations must develop from some common and underlying cause and were inherited.

Using other observational data, Norrie reported that she found specific dyslexia in "practically all" the parents of those dyslexic children she examined. Kagen stated his findings of a familiar·occurrence of dyslexia in 30 percent of his cases, and Ramer found the same to be true in 50-60 percent of his cases (Owen, 1978). Note that the method of approach in these studies is to identify rates of concordance within families. The inherent limitations of such a design will become evident in the discussion that follows.

Most of the more rigorous investigations of genetic influence in dyslexia have been conducted in Scandinavia. Hallgren (1950) studied the case and family histories of 276 dyslexic children. In 88 percent he found evidence of a reading disability in the immediate family of the child with dyslexia. As his selection of subjects and operational definition of dyslexia were quite rigorous, and as he included in his study a control group for comparison purposes, his results and conclusions must be attributed more weight than earlier observational reports based on a few cases. Statistical analysis of his data led him to conclude that specific dyslexia followed a dominant mode of inheritance. He theorized that dyslexia is determined by an alternate form of a gene, which is placed on a chromosome other than a sex chromosome.

Sladen (1971) disagreed with Hallgren's interpretation of his data regarding sex incidence and postulated that the character of genetic transmission has variable dominance in males and is largely recessive in females.

It can be argued that the occurrence of learning disorders in several generations of a family does not necessarily lead to the conclusion that the disability is genetically determined. Many characteristics or behaviors are perpetuated through generations within families on a cultural basis. As Owen (1978) suggests, "is it not possible that a bright parent who did poorly in school could, through deviant social learning patterns, inadvertently teach his or her bright children to perform poorly in school?" (p. 281).

More convincing evidence comes from the study of monozygotic and dizygotic twins. The Danish investigator Hermann (1959) assembled three such studies, one of Hallgren's and two of Norrie's. Altogether, he compared data from twelve pairs of monozygotic twins and 33 pairs of dizygotic twins. All twelve monozygotic pairs were concordant for dyslexia, while only 11 of the 33 dizygotic pairs (33 percent) were concordant. Hermann stated that these figures indicate with "all desirable clarity" that specific dyslexia is genetically determined. He went on to observe that, based on his sample, the fundamental disturbance in dyslexia also involves the individual's idea of direction in space, noting that dyslexics more frequently than normal readers showed right-left confusion, uncertainty in the naming of fingers, and difficulties in writing. He concluded that the underdevelopment of the individual's idea of direction in space was transmitted by dominant genes.

Genetic formulations attempt to identify the fundamental origins of dyslexia, but shed little light on the actual mechanism through which the observed language difficulty comes about. We now turn to investigators who attempt to specify its means of expression.

One area of focus by theorists concerned with determinants which explain and characterize the manifestation of specific dyslexia is the "maturational lag" hypothesis. This hypothesis postulates that reading disabilities reflect a lag in the maturation of the brain which differentially delays those skills which are in primary ascendancy at different chronological ages. More specifically, the skills which are delayed are thought to be those crucial to the early phases of reading, for example, learning to differentiate graphic symbols or the perceptual discrimination of letters. Underlying these delays, according to these theorists, is a lag in the maturation of the cerebral cortex; thus there is a disorder in central processing without the implication of damage, loss of function or permanent impairment (Satz, Rardin & Ross, 1971). This hypothesis would seem to explain Critchley's (1974) finding that many dyslexic children, particularly those who are highly intelligent, show spontaneous improvement in reading and writing skills, even without much help, often around the beginning of adolescence.

In response to critics who point out that for many or most dyslexics, the condition is not self-correcting as maturation evolves, the theory's proponents state their uncertainty as to whether the lag in cognitive-linguistic functions which is postulated to develop in older reading-disabled children reflect a transitory or more permanent defect in cognitive functioning. It is hypothesized that if the language disorder persists after maturation of the central nervous system is completed, then a permanent defect in function may occur. The maturational lag hypothesis continues to generate considerable research activity.

Conceptions of theorists who postulate a basic neurological abnormality underlying specific dyslexia fall into two broad categories: those who posit a focal maldevelopment of the brain, and those that emphasize a defect in the overall organization of brain functioning.

The focal theory was the first to be proposed. Hinshelwood (1917), a British physician referred to above, located the defect in the left angular gyrus. It soom became apparent that the postulation of such a unilateral abnormality was untenable because of the ease with which language functions can be transferred from one hemipshere to the other in young children (Benton, 1975).

Consequently, the idea that bilateral parietal maldevelopment may be the structural basis for dyslexia was advanced by several authors, most notably Geschwind (1962, 1970). His rather intricate theory focuses on the inferior posterior parietal area which serves as an assembly point for visual, auditory, and somesthetic impulses from the association areas and thus can serve the role of integrating information from them. It may provide a cerebral mechanism for formation of the crossmodal or intersensory associations, which may be the basis for the development and maintenance of skill in reading, as well as other language functions. Thus, he hypothesizes that faulty or delayed development of the posterior parietal region may prove to be the structural basis for specific failure to learn to read. Benton (1975) reviews several research investigations designed to test this theory and concludes that while several of the underlying assumptions in the theory are supported to some degree, as a whole it has not been substantiated. "If anything, the results tend to weaken the proposition that crossmodal associative capacity constitutes a specific foundation for reading" (p. 35).

Besides the parietal area, other areas of the brain have been singled out as possible loci of dysfunction resulting in reading problems. Silver (1970) refers to a neurohumoral imbalance affecting the reticular formation and the limbic system. And others, such as Frank and Levinson (1974) view dyslexia as influenced by cerebellar-vestibular dysfunction. These theories have not been extensively researched as yet.

Results of investigations differ, moreover, according to epidemiological characteristics of dyslexics studied, making theorizing more difficult. For example, McKeever and VanDeventer (1975) studied adolescents with chronic dyslexia and found, in contrast with other studies, that visual and auditory processing of simple language stimuli and auditory memory for verbal material were impaired. The authors conclude there is a left hemisphere visual association area functional deficit. This result would suggest that a selected group of dyslexics at a later age may show deficits which are not found in the younger dyslexics investigated.

Whether or not structural brain damage is present as a factor in dyslexia has certainly not been resolved. Positions taken in the literature range from one extreme to the other. While some dyslexics show strong indications of neurological impairment, a substantial number manifest no obvious abnormality. In the latter group, however, neurological "soft signs" are often present. Another view is that although there is no structural pathology, brain function is abnormal. The theory of cerebral dominance, with its emphasis on atypical patterns of neurological organization and development, is the best known and most widely researched of this type of theory. This theory of etiology, because of its relevance to the present research, will be explored in a separate section.

Dyslexia and Cerebral Dominance

The concept that disturbed hemispheric balance is responsible for specific dyslexia was explicated and brought into prominence by Orton (1926, 1928, 1937), as has been alluded to above, although the idea was mentioned by earlier writers. Orton found that children with dyslexia manifested some degree of lack of cerebral dominance, basing his conclusions on clinical observations of mirror-image errors in reading words, a higher incidence of nonconcordant eye and hand preference, and a greater frequency of absence of hand preference in children with reading problems as opposed to normal children. Some of his ideas have been applied in various treatment approaches with learning disabled children, such as the Doman-Delacato system, which emphasizes techniques designed to establish hemispheric dominance where it has not occurred.

The vast literature on laterality characteristics and reading skills does not lead to any simple generalizations. The results of earlier studies were inconsistent, with some investigators reporting a high frequency of anomolous hand and eye preference in poor readers and others finding little or no relationship between these variables and reading ability. Where high association has been reported, the subjects were mostly children referred to clinics or hospitals for neurological evaluation and in this sense "selected." Regarding hand preference, it has been established that dyslexic children are more likely to be "ill-lateralized" than left-handed (Naidoo, 1961; Shearer, 1968). Zangwill (1960) investigated a subgroup of "ill-lateralized" dyslexic children and found a high frequency of retarded speech development, defects of spatial perception, clumsiness, and related indications of defective maturation. On the other hand, one type or another of left-sided or mixed lateral preference is certainly not rare in children whose reading skills are adequate.

Nevertheless, Benton (1975) states that many of these essentially negative studies do find a weak trend in the direction of a higher frequency of deviant lateral organization in poor readers. Consequently, despite the negative tone of earlier results, clinicians have found it difficult to give up the idea that deviant lateral preference, presumably indicative of a cerebral dominance disturbance, plays a role in at least some cases of dyslexia. The field has become saturated with inconsistent results on the eye, hand, and foot preference studies in normal and disabled readers.

The hypothesis of abnormal cerebral dominance remained essentially untested in a rigorous way until the last decade. With the advent of "so-called" split-brain research, various methods became available for the study of hemisphere specialization which have made it possible to investigate localization of functions relevant to the manifestation of such syndromes as dyslexia.

This methodology involves the use of various perceptual tasks based on the fact that different types of stimuli may be presented in the left or right sensory (visual, auditory, and tactual) fields. As the connections from the sensory apparatus to the brain are predominantly crossed, the stimulation is initially transmitted to the contralateral hemisphere. Consequently, by presenting different stimuli in each sensory field and measuring accuracy or latency of perception, it is possible to determine which hemisphere is mediating responses and, thus, is dominating various functions. For example, Kimura (1961) adapted a dichotic stimulation technique to the study of cerebral dominance for hearing and vision by using a dichotic listening device and a tachistoscopic presentation that controls which half of the visual system is receiving stimulation and therefore to which hemisphere the information will initially be transmitted. Witelson (1976) has developed another bilateral stimulation technique using dichotomous tactual stimulation.

Most investigations employing these methods have used right-handed subjects exclusively, because research results suggest much more certainty about the cerebral specialization of function in right-handers than in sinistrals. Early neurological studies of patients with unilateral brain damage revealed that in right-handed people the left hemisphere is specialized for language (Geschwind, 1970) and the right hemisphere for nonverbal, visuospatial abilities (Milner, 1968); in the case of left-handed people, however, the distinction is not so clear, and there may be bilateral representation of language functions (Hecaen & Sauguet, 1971; Zangwill, 1960). Females are also often excluded as subjects, partly because of the lower incidence of dyslexia in females but also because recent research suggests that spatial processing may be bilateral in females (Witelson, 1976).

Using variations of these methods, investigators have focused on the possibility of abnormal left hemisphere specialization for language functions in dyslexic children, but results have been confusing and disappointing except in the most extreme cases of pervasive language dysfunction or dysphasic disorders. Contrary to the hypothesis of either delayed, diminished, or lacking left hemisphere specialization in dyslexics, the results of most of the studies indicate that children with reading problems do have left hemisphere dominance for language functions, as do normal readers. The few reports that do support some abnormality of cerebral dominance in dyslexic children have been suggestive at most and generally involve statistically nonsignificant differences between dyslexic and control groups (Bryden, 1970; Zurif & Carson, 1970).

As a consequence of these results which do not support the hypothesis of poorly lateralized linguistic functions in dyslexics, some researchers have begun to investigate other hypotheses generated within the framework of cerebral dominance theory. Witelson (1976) points out that the implicit assumption that the basic cognitive defect in dyslexia is a language defect may be erroneous and believes that functional specialization of the right hemisphere as well as that of the left hemisphere merits study. She explores two lines of reasoning which may indicate that abnormal right hemisphere specialization for spatial processing may be involved in dyslexia. First, the act of reading involves aspects of spatial processing, such as shape discrimination of words and letters, and memory of visual images of words. Several researchers have interpreted some of the reading errors of dyslexic children as reflecting difficulty in visual-spatial processing (Boder, 1973). Witelson also points out that Orton's hypothesis of abnormal cerebral dominance in dyslexia may be interpreted as indicating that the right hemisphere has too strong a role in processing the visual-spatial aspects of linguistic input. Secondly, Witelson discusses several studies that have indicated that atypical language representation may be associated not with lower verbal ability but with lower spatial ability. Levy (1969) studied individuals who had linguistic processing represented in the right hemisphere and found that spatial ability suffered because it is also mediated by the right hemisphere, which was consequently overloaded. Witelson suggests that the reverse may be true in dyslexics, i.e., that there is atypical spatial representation and that the left hemisphere is more involved in spatial processing than in normals. If this is true, such a neural organization could result in interference with the linguistic processing of the left hemisphere in dyslexics. The implication would be that this deficiency could lead to predominant use of a different cognitive mode, resulting in a more spatial, holistic approach to reading (as well as other cognitive tasks) and poor ability to utilize a phonetic analytic strategy. This hypothesis obviously has implications for the effectiveness of various teaching strategies with dyslexic children.

Results of Witelson's study of 98 dyslexic boys and 156 normal boys confirmed her hypothesis of bilateral representation of spatial processing in dyslexics, as opposed to normals. In her experiment she used bilateral presentation of tactually perceived "nonsense shapes" to determine hemispheric specialization for spatial processing; it seems likely that a purer measure of spatial processing would provide less confounding results. To reduce such confounding was one of the purposes of the study here. In addition, Witelson's research was performed on dyslexics referred to a clinic, and it has been pointed out that often findings on such populations are not replicated in school populations. Thus the study described here represents an attempt to replicate her findings of bilateral spatial processing in dyslexics in a school population, using the dichotomous nonsense shapes task.

CHAPTER 3

PROBLEMS AND HYPOTHESES

Witelson's research represents strong support for the existence of bilateral spatial functioning in dyslexics. One question that might be raised concerns the nature of the spatial task used to test her hypothesis. The Witelson study employed tactual discrimination of shape, an operation which might be most accurately described as tactual-spatial rather than purely spatial. Identification of tasks which specifically tap spatial functioning is problematic, in that any task necessarily employs some sense modality, thus confounding the measurement of central nervous system functioning. An experiment which measured spatial processing by means of some other modality and showed the same differentiation as that found in Witelson's tactual task would provide convergent support for the bilaterality concept, thus greatly strengthening it. Witelson's own attempt to do this produced equivocal results for a visual-spatial task; she attributed this to task difficulty level but it may also have been the result of the type of content used in the task. (She employed unfamiliar pictures of people, and the literature is unclear whether the processing of this type of task is purely spatial.)

In this investigation three tasks involving spatial processing were administered to an experimental group of dyslexics and to a control group of normal readers. The expectation was that the normal readers would show a significantly higher level of lateral specialization, i.e., their performance would indicate the right hemisphere is doing the processing of the task, while the dyslexics would show less lateralization, with both hemispheres participating in the spatial processing. Such an outcome would substantiate and extend Witelson's results.

Specific hypothesis were that on all tasks:

(1) In the normal group, subjects would perform significantly better when the stimuli were presented to the left hand or visual field, indicating the right hemisphere is the primary mediator of spatial functioning in these subjects.

(2) In the dyslexic group, the difference between performance on right-sided and left-sided tasks would not be significant, indicating bilateral representation of spatial functioning.

CHAPTER 4

METHOD

Subjects. The subjects in the dyslexic group were 35 right-handed boys, aged eight through twelve, who were identified by the Des Moines school system as children with learning disabilities. They were drawn from three elementary schools in different areas of the city in an effort to provide a mix of socio-economic backgrounds. To be included in the study, each subject had to be reading at least 1.5 grade levels below the level that would be expected at his chronological age, and have a WISC-R Performance IQ of 85 or higher.

In the control group, subjects also were 35 right-handed boys from the same schools as the experimental group. They were matched for age with the dyslexic subjects and also had a WISC-R Performance IQ of 85 or higher. Control subjects were reading at or above the grade level corresponding to their chronological age and had shown no difficulty in reading throughout their school career.

No subjects were included in either group who were on medication for behavioral problems, had documented brain damage or other significant neurological abnormality, or manifested primary emotional disturbance. Subjects had adequate visual acuity, had been exposed to the customary educational opportunities, and used English as their first and main language.

Procedure. Three spatial tasks were administered to all subjects. They will be described in detail below. In addition, as a further check on handedness, each subject was asked which hand he used for writing, eating, and throwing a ball, and those who did not indicate unequivocal right-handedness in all three areas were eliminated. The performance section of the WISC-R was administered to all control subjects for whom scores were not on file, and those with scores below 85 were not included in the study. It should be noted that the WISC-R's administered in the course of the study were obviously given by a tester different from the individuals who tested the subjects with scores on file; consequently, scores may not be directly comparable. A description of the three experimental tasks follows.

Task I: Tachistoscopic Presentation of Spatial Stimuli. The tachistoscopic paradigm was used as one method of studying hemisphere specialization for spatial processing, in the visual modality as, with a tachistoscope, stimuli may be presented exclusively to one visual field, while the subject fixates on a central point. Several different types of stimuli which require the visual perception of spatial relationships have been utilized in research on hemispheric specialization, for example, faces, slanted lines, and dot patterns (White, 1969; Kimura & Durnford, 1974). In this investigation a modification of a task designed by Kimura (1969) was employed, as her results indicated its usefulness in tapping spatial functioning mediated by the right hemisphere in normal subjects, and its difficulty level is such that it seemed reasonable to expect it to be readily understood and executed by children. This expectation was substantiated in piloting.

A series of 32 cards with 2 squares 7.62 centimeters on a side, with the fixation point midway between them was tachistoscopically presented to each subject. At each presentation a single dot was shown in one of 16 positions in either the left or right square. The subject was asked to report the location of the dot using as a reference a card, mounted above the tachistoscope, indicating all 16 positions used (See Appendix A).

Exposure time varied for each subject and was determined by a series of pretest trials of the same task. Starting with an exposure time of 20 milliseconds, the subject's accuracy on ten presentations was recorded. The exposure time was increased on succeeding series until he was correct in locating 7 of the 10 dots presented. The established 70% accuracy exposure time was then used for each of his test trials. Four subjects (one control, three dyslexic) were eliminated from this part of the investigation because they were not able to attain the required accuracy level even at 120 milliseconds, a latency which often permits unwanted eye movements.

Stimuli were presented to the subjects by means of a Gerbrands Harvard 2-channel Tachistoscope. With this type of tachistoscope the subject's eyes are approximately two feet from the exposure field. Each subject was asked to fixate a central point, and before each stimulus presentation, a ready signal was given.

As stimulation in each visual hemifield is transmitted initially to the contralateral hemisphere, using a central fixation point it can be determined which hemisphere is primarily mediating each response. Thus responses to dots located in the left square are assumed to be mediated by the right hemisphere, and those to dots in the right square by the left hemisphere. Comparison of right-left scores for each group can indicate which hemisphere is more dominant in processing spatial information received through the visual modality.

Task II: Dichotomous Tactual Stimulation. The second method used in investigating hemispheric specialization for spatial processing was Witelson's nonsense shapes task, discussed earlier. It has been described in detail by Witelson (1974) and was replicated in this investigation as precisely as possible. The task requires spatial perception of pairs of competing nonsense shapes through touch only. In each trial the subject was instructed to examine tactually, out of view, two different styrofoam shapes simultaneously for ten seconds, one with each hand, using only the first and middle fingers. (Pretest trials were given with different shapes to familiarize each subject with the task and provide practice in simultaneously feeling two stimuli.) Then a visual display of six shapes (the two correct shapes, two of the other test stimuli, and two distractors) was presented to the subject, and he was asked to select the two he experienced and to indicate them by touching them with his left hand. A different display was used for each trial. Each presented the six stimuli in an arrangement designed so that one shape was in the center of a cluster to discourage left-right scanning. The display stimuli were counterbalanced for position, frequency of occurrence, and associated stimuli. There were ten trials, with each of the ten shapes being presented to each hand. (See Appendix B). The scores obtained were the number of left and of right hand objects correctly identified.

Witelson's rationale for this task is as follows. Shape discrimination that is not amenable to verbal encoding has been shown to be primarily dependent on right hemisphere functioning in adults (Milner and Taylor, 1972; Nebes, 1972). Consequently, shape discrimination was selected as the cognitive task, and it was constructed to be as non-linguistic and right-hemisphere dependent as possible. The stimuli are meaningless shapes, not readily labeled. The items in the visual recognition display were designed with details similar to the felt stimuli, so that an accurate response depends on a gestalt perception of the whole stimulus, rather than on analysis of details, which may be a left hemisphere function (Witelson, 1976a).

Tactual shape discrimination has been shown to be dependent on only the contralateral somesthetic pathways (Sperry, Gazzaniga & Bogan, 1969). In this task two different stimuli are presented at the same time, one to each hand, producing a competing situation in the processing of left and right inputs in the central nervous system. Thus higher left hand scores would indicate right hemisphere dominance in spatial processing, and higher right hand scores would point left hemisphere dominance.

Task III: Spatial Orientation Task. The third method used in investigating hemispheric specialization in spatial processing was a task developed by Semmes, Weinstein, Ghent and Leuker (1955), which required brain-injured subjects to follow routes represented on maps. A recent experiment by Whitehouse (Note 1) found that normal subjects performed significantly better on trials where the stimulus was presented to the left hand than to the right hand, indicating the task seems to be responsive to right hemisphere spatial processing.

In the study by Semmes et al., both visual and tactual maps were used; only the latter were employed in this investigation. As it would be impossible to determine which cerebral hemisphere was involved in processing of visual material without the aid of a tachistoscope. Eight plywood maps, or diagrams of paths, were presented one at a time to each subject. Nine orientation points on the maps were represented by the heads of upholstery tacks, and the path was indicated by a continuous card which wrapped around the tacks at the turning points. A piece of tape over the card indicated the starting point and a knot in the card, the end of the route (See Appendix C). The nine points on the maps represented nine circular blue spots on the floor of the room arranged in a 3 by 3 square, which measured 5 feet on a side, in which the subjects were instructed to walk through the indicated path.

After initial instruction with the subjects viewing the maps and then walking out the represented patterns the test maps were presented to each subject hidden from view by being enclosed in a loose bag with a shoulder strap. The subject was instructed to place his right or left hand inside the bag so that he could feel the map, while balancing the bag with his free hand. An orientation point was provided by a strip of tape across the bottom of the map which corresponded to a strip of tape below the bottom three spots on the floor. Each subject was instructed to keep the map before him as he progressed along the route, and to hold it in a constant orientation with respect to his body. Thus the map was incorrectly oriented to actual directions much of the time as the subject made indicated turns. It was therefore necessary for him to effect a translation of the spatial coordinates in order to reproduce the maps correctly. Four of the maps were perceived with the left hand and four of corresponding difficulty level with the right hand. There were no time limits.

The path followed by each subject in response to each of the maps was scored right or wrong as a whole. Subjects were allowed to correct incorrect turns if they did so before reaching the next turning point. Any other errors resulted in a score of zero for that map. Each subject received a total right-handed score and a total left-handed score. Again it is assumed that higher left hand scores would indicate right hemispheric specialization for spatial processing, and higher right hand scores would point to left hemispheric specialization.

CHAPTER 5

RESULTS AND INTERPRETATION

Task I: Tachistoscopic Presentation of Spatial Stimuli

As described in detail above, this task involved tachistoscopic presentation of a 32-stimulus array (16 to each visual hemifield), and a comparison of the normal and the dyslexic subjects with respect to two questions: Do the normal subjects show superior task performance when the stimulus is presented to the left hemifield as compared to the right, and do the dyslexic subjects, by contrast, show no significant hemifield disparity? Neither of these expected results was confirmed by the actual data. While the normal subjects showed a trend in favor of the left side, the difference was not statistically significant. And the dyslexics, contrary to the hypothesis, showed a significant difference in favor of the left side. Table 1 summarizes these results.

It should be noted that in overall accuracy the normal group was significantly superior to the dyslexic group (overall normal mean of 23.03 and dyslexic mean of 21.41, $\underline{p} < .05$). Normals were also superior in performance when the stimulus was presented to the right hemifield ($\underline{p} < .05$). Left hemifield scores did not differ significantly between groups. Accuracy increased with age similarly for both groups.

Table 1

Mean Number Correct Scores for
Left and Right Hemifields for
Tachistoscopic Presentation of Spatial Stimuli

Group	N	Left (16 Presentations)	Right (16 Presentations)	t
Normals	34	11.82	11.21	1.0988
Dyslexics	32	11.34	10.06	2.0000*

*Significant at the .05 level.

A potential complicating factor was that for Task I only, subject IQ scores were found to have a low but significant correlation with task performance. (The mean IQ for the dyslexic subjects was 97.86; for control subjects it was 106.63.) Statistical reformulation of the Table 1 accuracy means with the influence of IQ removed by an analysis of covariance produced revised means, presented here in Table 2.

Table 2

Revised Mean Number Correct Scores for
Left and Right Hemifields for
Tachistoscopic Presentation of Spatial Stimuli

Group	N	Left (16 Presentations)	Right (16 Presentations)	F (Side Factor)
Normals	34	11.48	10.86	5.0926*
Dyslexics	32	11.71	10.43	

*Significant at the .05 level.

Employment of this procedure precludes the use of individual *t* tests, but the available *F*-ratio of 5.9026, which is significant, indicates that for both groups of subjects, taken together, the observed superiority of left side performance is significant. It is noteworthy that when overall accuracy scores of normals versus dyslexics are corrected through this procedure, the overall superiority of normals over dyslexics disappears.

The results for Task I do not present a clear picture leading to support of the stated hypotheses. On this task, it appears that both groups perform as if their spatial processing is somewhat specialized in the right hemisphere, and that this specialization is no more pronounced for the normal readers than for the dyslexics. A more complete discussion of this and related points will appear in the subsequent chapter.

Task II: Dichotomous Tactual Stimulation

The second task employed 20 nonsense shapes which the subject explored tactually out of view (ten with each hand), simultaneously with the right and left hands. The key comparison was between the number of shapes identified with the left hand versus the right hand. This task was specifically designed to tap performance in a situation where competing messages are being transmitted to both hemispheres. The questions here were the same as for Task I: Do normals show superiority of left hand over right hand performance, and do dyslexics show no such left-right disparity? As shown in Table 3, the normal subjects displayed a superiority of right hand over left hand performance, the exact opposite of the expected result, and the difference is statistically significant. The dyslexics showed the same disparity in the same direction, and the difference is more pronounced than the controls.

Again, the results obtained do not support the stated experimental hypotheses. The data in Table 3 do leave open the possibility of additional interpretations, however. There is a suggestion, for example, that there may be a stronger tendency for dyslexics to employ the left hemisphere for spatial processing than there is for normals to do so, even though the expected left hand superiority for normals was not obtained.

Table 3

Mean Number Correct Scores for
Left and Right Hand Performance for
Dichotomous Tactual Stimulation

Group	N	Left (10 Shapes)	Right (10 Shapes)	t
Normals	35	5.97	6.60	1.7176*
Dyslexics	35	4.94	6.43	5.3301**

*Significant at the .05 level.
**Significant at the .001 level.

On this task the overall accuracy of the normals was higher than that of the dyslexics (overall normal mean of 12.57, dyslexic mean 11.37, $p < .01$), and the difference was significant. Normals were also superior to the dyslexics when stimuli were presented to the left hand ($p < .001$), but there was no significant difference between right hand scores. Accuracy increased similarly with age for both groups. The Discussion Chapter will offer further interpretations of the Task II results.

Task III: Spatial Orientation Task

This task made use of a special type of tactual map, to be felt with the left or right hand out of view. The subject feels each of eight maps, four with each hand, and follows it by walking a grid on the floor which the map represents. As in Task II, high left-handed scores would indicate right hemisphere spatial processing, and high right hand scores would correspond to left hemisphere functioning. Table 4 summarizes the obtained accuracy scores for Task III.

The pattern of scores indicates only a very slight trend in the expected direction, and the results are not significant. The normal subjects do show a slight left-handed superiority, and this trend is slightly stronger than the similar left-right disparity for dyslexics, but the results could in no way be interpreted as supporting the stated hypotheses, as they fall far short of statistical significance. Although the dyslexics' insignificant difference between right and left scores would seem to support the hypothesis for that group, the significance of this is questionable since the controls show the same lack of disparity.

Table 4

Mean Number Correct Scores for
Left and Right Hand Performance on
Spatial Orientation Task

Group	N	Left (4 Maps)	Right (4 Maps)	t
Normals	35	2.91	2.77	.5005
Dyslexics	35	2.03	1.01	.3948

As in Task II, the overall accuracy of the normal group was superior to that of the dyslexics (overall normal mean of 5.69, dyslexic mean of 3.94, $p < .001$). There were no significant differences in either right hand or left hand performance between groups. In summary, on Task III there were no significant right-left differences for either normals or dyslexics, but results showed a strong superiority of normals over dyslexics in accuracy of performance. Implications of these findings will be pursued in the Discussion Chapter.

The absence of consistent trends across the three tasks presents a picture of extremely variable results, making it difficult to draw any generalizations or conclusions about the group results as a whole. Even though the groups did not display consistent across-task differences, it was hypothesized that subjects within the groups might perform in the expected manner. To determine whether or not subjects showed consistency of performance across tasks, results for individual subjects in both groups were examined. In other words, results were analyzed to determine if the subjects who showed a left-sided superiority on one task were also likely to manifest the same tendency on the other tasks. This was assessed by calculating correlation coefficients between subjects' left-right difference scores on one task and their left-right difference scores on the other tasks for each group of subjects. All the resulting correlation coefficients were insignificant, thus confirming the apparent task-dependent nature of the left-right differential.

CHAPTER 6

DISCUSSION

The present study was conceived for the purpose of validating and extending a theory which had already been investigated by Witelson (1976b) using a similar methodology. Witelson hypothesized that specific reading disability, or dyslexia, is associated with a failure to establish cerebral hemispheric specialization for spatial functioning, that is, spatial processing is bilateral in dyslexics. This bilaterality would manifest itself in the form of a decreased left-right performance disparity for dyslexics on tasks which tapped spatial processing. Normal, or highly hemispherically differentiated subjects, would show much better performance on spatial tasks where messages were transmitted to the right hemisphere (that is, presented to the left hand or left visual hemifield) than when the messages were transmitted to the left hemisphere (or right hand or right visual hemifield), according to the hypothesis. Dyslexics, when exposed to the same stimulus materials, would show no significant difference in accuracy for stimuli presented to either side. Some studies have obtained results confirming this hypothesis, but other investigations have failed to substantiate it (Witelson, Note 2).

In the present study, dyslexic and normal subjects performed three separate tasks which were designed to assess spatial processing. The first task involved visual presentation of a stimulus to a single hemifield, and the other two tasks relied on tactual stimuli felt with either the right or left hand. The results presented an overall picture which was non-confirmatory.

To summarize the results, on the visual processing task, both normal and dyslexic subjects showed right hemisphere superiority, with the disparity more pronounced in the dyslexic group. For the shape discrimination task, both groups showed superiority of left hemisphere processing, with the difference again more pronounced in dyslexics. With regard to the third, map-reading task, no significant left-right differences were found in either group of subjects, but there were strong differences in accuracy on both sides, favoring the control subjects. Thus, the pattern of performance was different for each task, and there appears to be no clear across-task pattern.

The possible reasons for this generally non-confirmatory result need to be explored. It may be that Witelson's hypothesis of bilateral spatial processing by dyslexics is simply in error. It will be recalled that the expected pattern of results has been obtained in some investigations and not in others (Witelson, Note 2). The present study would need to be added to the list of attempted replications which failed to produce the expected result.

Another explanatory possibility would be that the basic hypothesis is correct, but that experimental factors influenced the results. Differences in subject selection may be considered. It seems unlikely that differences between Canadian and U.S. school children could account for differences in results, especially since some studies in the United States have been confirmatory (e.g., Dawson, Note 3). The population from which the samples of dyslexics were drawn - Witelson's subjects were referred by "clinical sources" and this study used a school sample - may be a partial explanation for the differences in dyslexic performance, but does not account for the unexpected results for the normal readers. Although subject selection criteria for this study and Witelson's study appeared essentially the same, there might be subtle, undetected differences in subject groups.

It seems possible that while, taken as a whole, the sample of dyslexics did not support the hypothesis, a subgroup within the sample which performed in the expected manner on one, two, or all three of the tasks might be characterized as displaying bilateral spatial processing. This may relate to the definitional confusion surrounding the concept of dyslexia referred to earlier; that is, if the definition of dyslexia could be refined to delineate specific subtypes, those who manifest bilateral spatial processing might comprise one such group. A suggested direction for future research might be to collect data on those who demonstrate cerebral dominance problems to determine if particular variables distinguish these "expected performers" from the rest of those now defined as dyslexic.

An additional consideration has to do with difficulties in defining tasks and assuring their sensitivity to hemispheric dominance. This is basically a question of task validity: do the tasks measure what they are designed to measure: For example, the second task was specifically designed to tap purely spatial processing, but, as Witelson points out, subjects are nevertheless free to choose their own strategies for execution of the task and may be finding some way to employ verbal mediation, i.e., left hemisphere functioning, as an aid to task performance (Witelson, Note 2). Or, despite instructions to explore the stimuli simultaneously with both hands, some subjects may have concentrated more on the right hand. In addition, on task three, one complicating factor may have been that it was presented with no time limit; thus there would be ample time for information to be transmitted from one hemisphere to the other and thus allow verbal mediation of the task, which was designed to be nonverbal in nature.

One finding of the study is irrelevant to the concept of cerebral dominance but may be otherwise significant in the etiology of dyslexia. The pronounced accuracy differences between dyslexics and normal readers on the map-reading indicates that the former group had considerably more difficulty with this task. It is interesting to note that in previous research employing this task with brain-injured adult subjects, it was found that subjects with localized brain damage in the parietal area had the greatest difficulty with the spatial orientation required by this task (Semmes et al., 1955). This suggests that the dyslexic group here shares some performance characteristics with persons with parietal lesions and seems to support those, most notably Geschwind (1962), who postulate parietal maldevelopment as etiologically significant in dyslexia, as discussed in Chapter 2.

Overview

Because of the apparently atypical nature of the control subjects and the subsequent inconclusive pattern of results, there is no clear statement that can be drawn from the results of the present study. Only isolated, partially confirmatory results appear in a generally non-confirmatory pattern.

The implication is that research needs to proceed in the direction of finding tasks which more clearly preclude verbal mediation strategies and thus truly measure functioning of a single hemisphere. There also needs to be improvement in methods of defining and selecting dyslexic subjects. From the present study, it appears that some of the individual dyslexic subjects within the selected sample perform the way dyslexics were expected to perform, while others do not. What are the key characteristics of this subgroup, and how can they be identified? The impaired reading of the subjects who did not perform as expected may represent a separate type of dyslexia, due to factors other than faulty hemispheric specialization. This further reinforces the need to specify subgroups within the broad category of dyslexia, which would seem to offer the most promising avenue along which to proceed with further research into dyslexia and hemispheric dominance.

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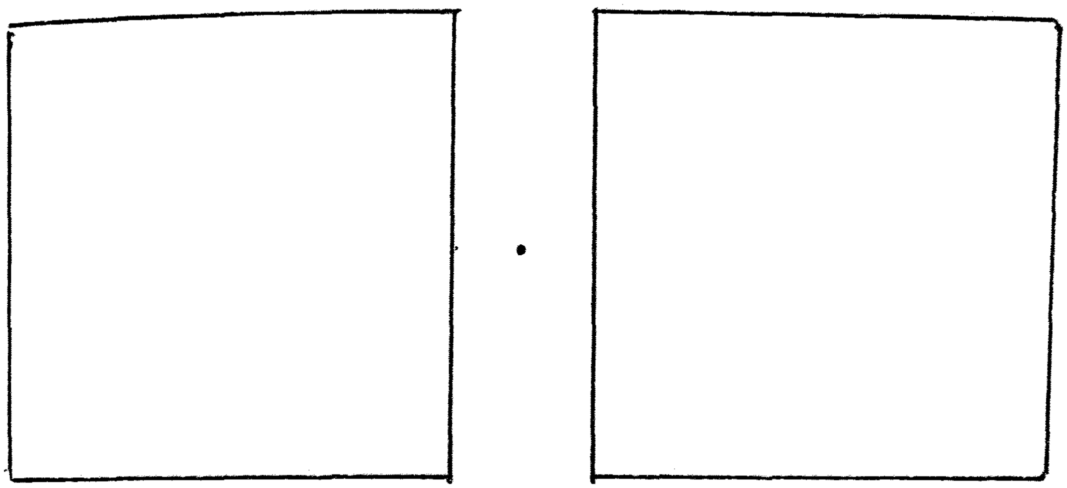
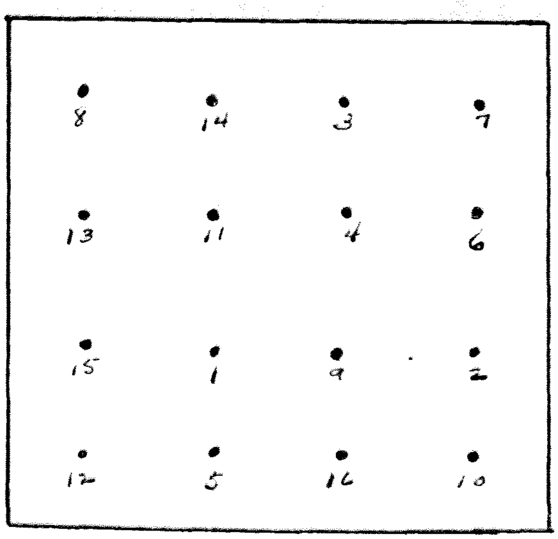
APPENDIXES

APPENDIX A

MATERIALS USED IN TASK I



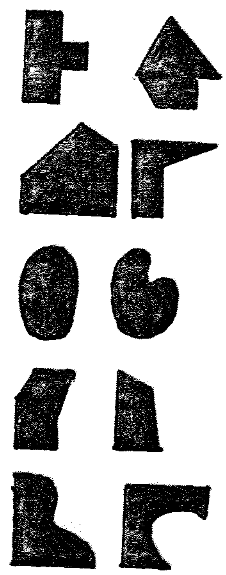
Pre-exposure field used in Task I.



Reference card used in Task I.

APPENDIX B

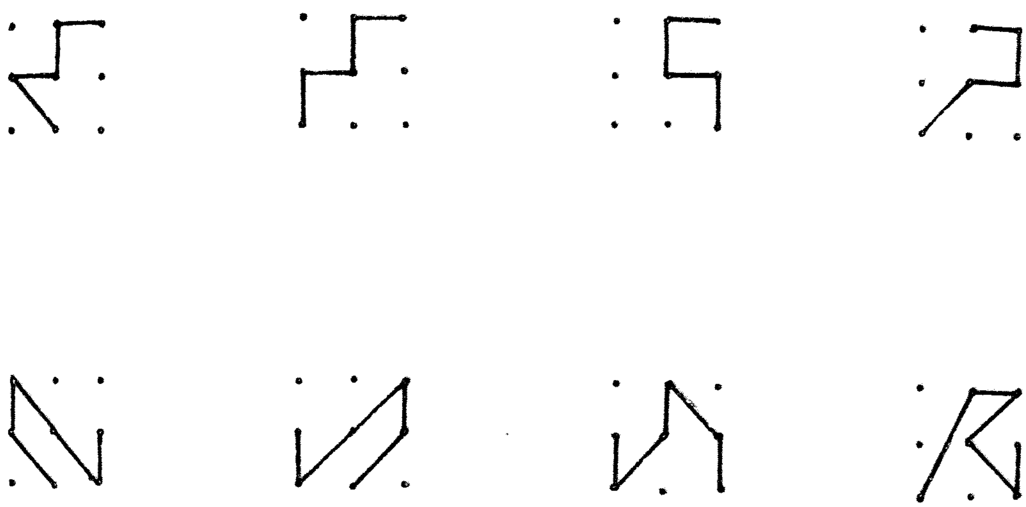
MATERIALS USED IN TASK II



The five pairs of stimuli for Task II (after Witelson, 1974).

APPENDIX C

MATERIALS USED IN TASK III



Tactual maps.